Impact of improved bedrock on ice sheet models

Sophie Nowicki and Robert Bindschadler, Code 614.1, NASA GSFC

Despite being a fundamental input for ice sheet models, the bedrock beneath the Greenland and Antarctic ice sheets is poorly known. The basal topography influences the current state of the ice sheets, and their evolutions. Ice sheet numerical studies, such as SeaRISE, that are targeted at informing the 5th IPCC report on the potential contributions of ice sheets to future sea level, are therefore limited by this basal boundary condition.

Improved knowledge of the basal topography beneath current ice sheets is only possible with observations by a suite of airborne instruments, such as the Operation Icebridge mission. We show that incorporation of a surveyed basal feature, comparable to Grand Canyon, in the bedrock dataset improves simulations of the present day ice velocity.

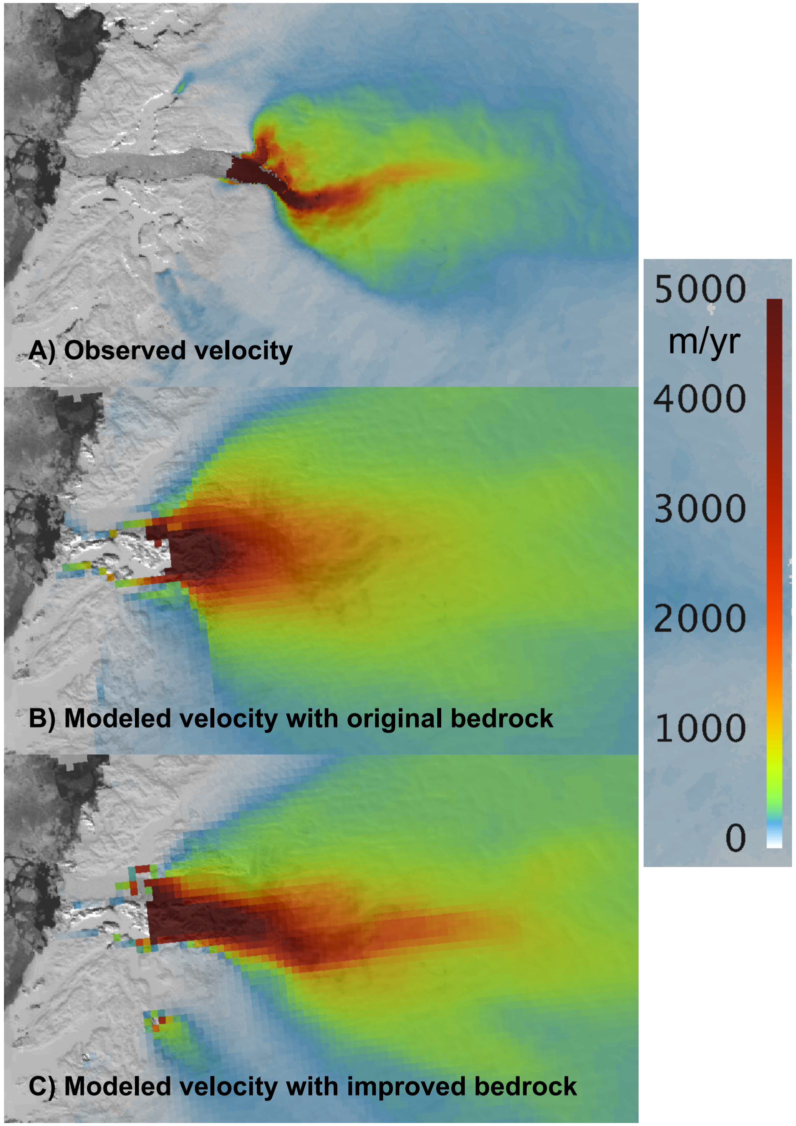


Figure 1: Present day surface velocity simulated with the ice sheet model PISM and resulting from different bedrock condition in Jakobshavn Isbrae, Greenland.

Name: Sophie Nowicki and Robert Bindschadler, Code 614.1, NASA/GSFC
E-mail: sophie.nowicki@nasa.gov, robert.a.bindschadler@nasa.gov
Phone: 301-614-5458, 301-614-5707

References:
Operation IceBridge description website:
http://www.nasa.gov/mission_pages/icebridge/index.html

Parallel Ice Sheet Model (PISM) description website:
http://www.pism-docs.org/wiki/doku.php

Sea-level Response to Ice Sheet Evolution (SeaRISE) project description website:
http://websrv.cs.umt.edu/isis/index.php/SeaRISE_Assessment

Data Sources: Operation IceBridge is a NASA airborne mission funded by the NASA Cryospheric Science and the NASA Airbone Science programs. SeaRISE is a community organized effort, lead by NASA/GSFC, and partially funded by the NASA Cryospheric Science program. The PISM model simulations are courtesy of A. Aschwanden and E. Bueler, University of Alaska. The background image is a MODIS imagery, courtesy of M. Fahnestock, University of New Hampshire.

Technical Description of Images:
Figure 1: Comparison of A) observed InSAR ice surface velocity (Joughin et al., 2010) to modeled velocities resulting from the use of B) “original” bedrock (Bamber et al., 2001) and C) “improved” bedrock that includes the canyon in Jakobshavn Isbrae, Greenland. The simulations are from the PISM ice sheet model, at a horizontal resolution of 2km, which is the finest grid resolution ever done on a whole Greenland scale with an ice sheet model that goes beyond the shallow ice approximation.

Scientific significance: This example demonstrates the effect of improved bedrock knowledge beneath the ice sheets on ice flow, by including bedrock canyons measured by Operation IceBridge in the SeaRISE dataset. The agreement between simulations and observations is expected to continue to improve with finer model resolution and as our knowledge of the bedrock ameliorates.

Relevance for future science and relationship to Decadal Survey: The Decadal Survey identifies ice sheet, and their contribution to sea-level, as key issues in Climate Variability and Change. SeaRISE provides guidance for addressing the scientific and societal important issue of ice sheet induced sea-level rise using ice models by providing forcing experiments and a crucial dataset that comprise, for example, of the bedrock topography.

Aquarius Successfully Launched

Bryan Franz, Code 614.2, NASA GSFC

The Aquarius Mission will:

- Investigate the links between the global water cycle, ocean circulation and climate
- Make global, space-based measurements of Sea Surface Salinity (SSS)
- Provide 0.2 psu (practical salinity unit) accuracy at monthly, 150 km resolution
- Observe and model seasonal and year-to-year variations of SSS, and how these relate to changes in the water cycle and ocean circulation
- Yield an unprecedented view of ocean’s role in climate and weather

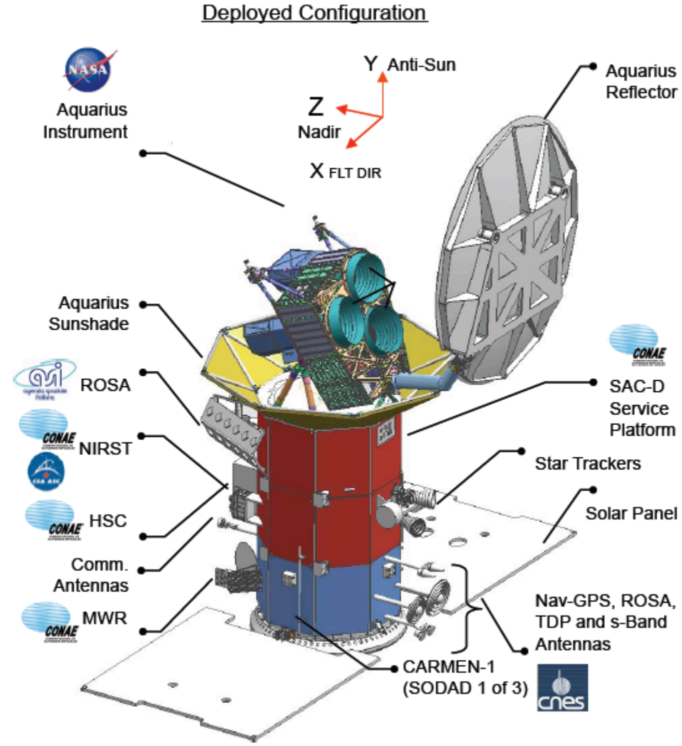


Figure 1: Schematic of the SAC-D Spacecraft

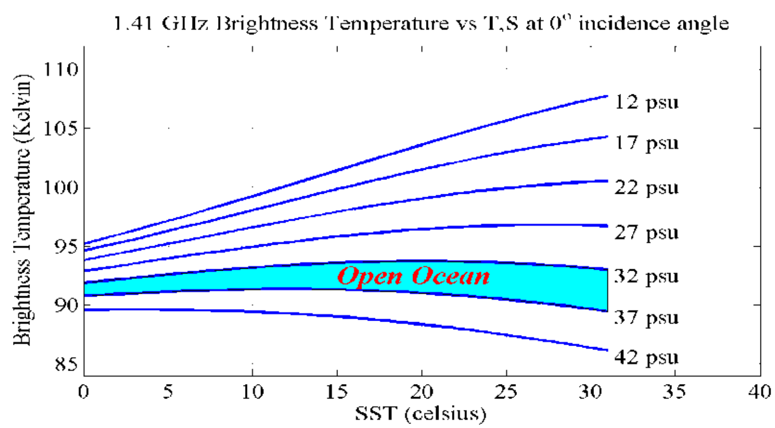


Figure 2: Salinity Measurement Concept

Name: Bryan Franz, Code 614.2, NASA/GSFC
E-mail: bryan.a.franzd@nasa.gov
Phone: 301-286-5429

References:
1.http://aquarius.nasa.gov/
2.Frank J. Wentz and David M. Le Vine, "Aquarius Salinity Retrieval Algorithm: Final Pre-Launch Version", Algorithm Theoretical Basis Document, RSS Technical Report 011811, 18 January 2011.
3.Lagerloef, G., C. Swift and D. LeVine, Sea surface salinity: The next remote sensing challenge, Oceanography, 8, 44-50, 1995.

Data Sources: simulated.

Technical Description of Image:

Figure 1: Schematic of SAC-D Spacecraft showing the Aquarius radiometer and scatterometer, as well as the Radio Occultation Sounder (ROSA), High Sensitivity Camera (HSC), New InfraRed Sensor Technology (NIRST), and the Microwave Radiometer (MWR).

Figure 2: Aquarius salinity measurement concept. Integrated L-band ultra-stable microwave radiometer-radar, 3 fixed beams, 390 km wide swath, 7-day repeat polar orbit. Salinity changes the emissivity of the ocean surface, which changes the observed brightness for a given surface temperature. Emmisivity varies most significantly with salinity in the microwave spectral regime. Radar scatterometer is required to correct for wind roughness, the largest uncertainty error source. Monthly averages are used to reduce measurement noise and achieve 0.2 psu RMS accuracy.

Scientific significance: Aquarius will contribute to a better understanding of ocean circulation, the prediction of changes in this circulation, and its impact on Earth's climate and water cycle.

UTILIZATION OF ANCILLARY DATA SETS FOR SMAP ALGORITHM DEVELOPMENT

Peggy E. O’Neill, Code 614.3, NASA GSFC

- Soil moisture is an important component of the Earth’s water and energy balance, and is relevant to many applications of societal benefit. In order to retrieve soil moisture accurately from SMAP microwave data, a variety of global static and dynamic ancillary data are required. The choice of which ancillary datasets to use for SMAP products will be based on a number of factors including availability and ease of use, their inherent error and resulting impact on SMAP retrieval accuracies, and compatibility with similar choices made by ESA’s SMOS mission.

- Errors in ancillary data are factored into the SMAP soil moisture retrieval algorithm error budget needed to retrieve soil moisture to the required mission accuracy of 0.04 cm^3 / cm^3.

ERROR BUDGET	Roughness h	Vegetation scattering albedo	Sand fraction	Clay fraction	0-5 cm Soil Temp	Vegetation water content	Open Water fraction	Brightness Temperature
RMSE	5%	5%	5%	5%	2 K	10%	10%	1.3 K

Examples of two SMAP ancillary data parameters:

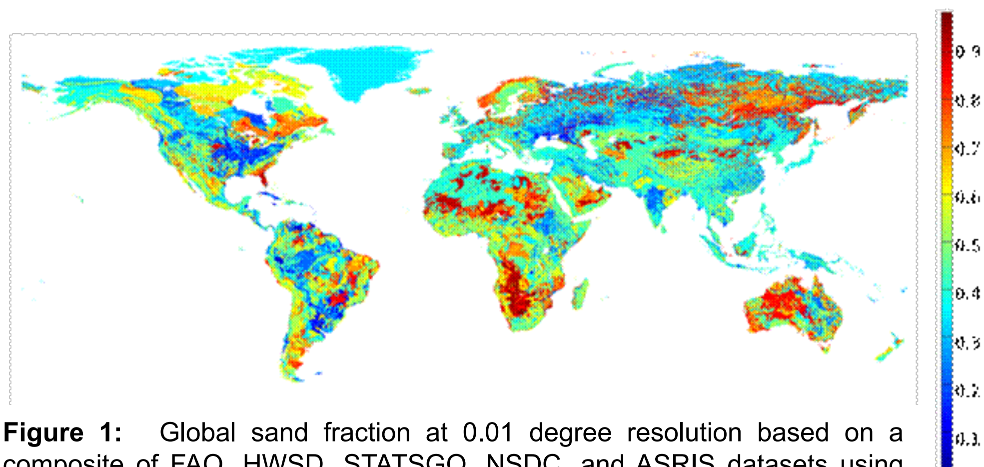
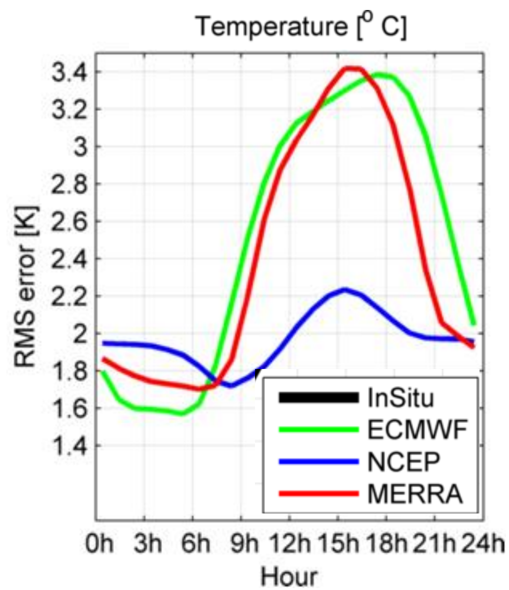


Figure 1: Global sand fraction at 0.01 degree resolution based on a composite of FAO, HWSD, STATSGO, NSDC, and ASRIS datasets using best available source for a given region.

Figure 2. Accuracy of 0-5 cm soil temperature derived from three NWP models when compared against *in situ* soil temperature data from the Oklahoma Mesonet for years 2004 and 2009. At the SMAP overpass time of ~6 am, all synchronized NWP-derived surface soil temperature products have errors below 2 K (just within the error budget allocation).



Name: Peggy E. O'Neill, Code 614.3, NASA GSFC
E-mail: Peggy.E.ONeill@nasa.gov
Phone: 301-614-5773

References:

O'Neill, P., E. Podest, and E. Njoku, "Utilization of Ancillary Data Sets for SMAP Algorithm Development and Product Generation," Proc. of IGARSS'11, IEEE, Vancouver, BC, Canada, July 24-29, 2011.

National Research Council, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond," pp. 400, 2007.

Entekhabi, D., E, Njoku, P. O'Neill, K. Kellogg, plus 19 others, "The Soil Moisture Active Passive (SMAP) Mission," *Proceedings of the IEEE*, Vol. 98, No. 5, May, 2010.

Das, N. and P. O'Neill, "Selection of Soil Attributes Datasets for the SMAP Mission," SMAP Science Document #xz, Draft 1.1, JPL, Dec., 2010.

Chan, S., "Selection of a Water-Land Fraction Dataset for the SMAP Mission," SMAP Science Document #xx, Draft 1, JPL, November, 2010.

Holmes, T., T. Jackson, R. Reichle, and J. Basara, "An Assessment of Surface Soil Temperature Products from Numerical Weather Prediction Models using Ground-based Measurements," in revision, *Water Resources Research,* 2011.

Das, N., "Evaluation of Urban/Rural Datasets for the SMAP Mission," SMAP Science Document #xy Draft 1.0, Jet Propulsion Laboratory, March, 2011.

Data Sources: The SMAP Science Definition and Algorithm Development Teams are currently assessing all datasets available for each needed ancillary data parameter. Preliminary selection of primary sources for each parameter should be completed by September 2011. Key factors considered in the ancillary data selection are latency, spatial resolution, temporal resolution, global coverage, accessibility/ease of use, and quality checks/internal error. All decisions regarding SMAP ancillary data sources will be fully documented by the SMAP Project and made available to the user community.

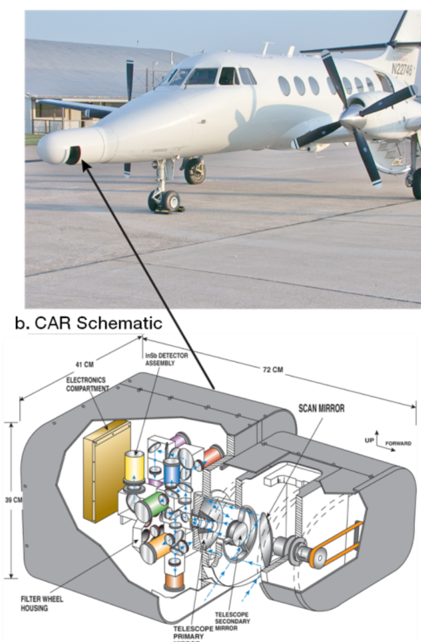
Technical Description of Image: The Soil Moisture Active Passive (SMAP) mission, with a scheduled launch date of October 2014, is the first Earth observation satellite being developed by NASA in response to the NRC's Earth Science Decadal Survey. Once launched, SMAP will provide high resolution global mapping of soil moisture and freeze/thaw state every 2-3 days on nested 3, 9, and 36-km EASE grids, utilizing an L-band radar and an L band radiometer sharing a single 6-meter rotating mesh antenna. In order for soil moisture and freeze/thaw to be retrieved accurately from SMAP microwave data, a variety of global static and dynamic ancillary data are required. Static data include parameters such as permanent masks (land / water / forest / urban / mountain), the grid cell average elevation and slope derived from a DEM, open water fraction, and soils information (primarily sand and clay fraction). Dynamic ancillary data include land cover, surface roughness, precipitation, vegetation parameters, and effective soil temperatures. Measurements from the SMAP radar will be used to provide information primarily on transient water and frozen ground. Ancillary data will also be employed to set flags which help to determine either specific aspects of the processing or the quality of the retrievals.

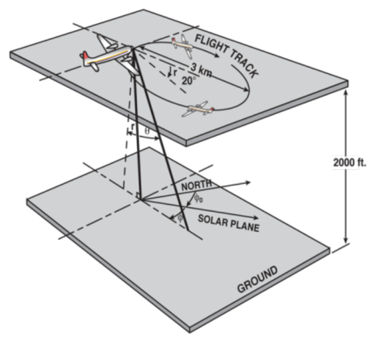
Scientific significance: Algorithms being developed for the SMAP mission require a variety of both static and ancillary data on a global scale. Fourteen different ancillary data parameters have been identified by the SMAP team as needed for the generation of all mission Level 2 products. Wise choices in ancillary data will help to enable SMAP to provide new global measurements of soil moisture and freeze/thaw state at the targeted accuracy necessary to tackle hydrologically-relevant societal issues.

Relevance for future science and relationship to Decadal Survey: Soil moisture is a critical control on water and energy cycles, as well as weather, climate, hydrological and agricultural prediction. Knowledge of the errors inherent in the ancillary data is needed to evaluate the accuracy of the retrieved soil moisture and freeze/thaw products.

Variability in the BRDF at different spatial scales over a mixed agricultural landscape as retrieved from airborne and satellite spectral measurements

Miguel O. Román, Code 614.5, NASA/GSFC





d. Cloud Absorption Radiometer (CAR) Parameters

Angular scan range	190°
Instantaneous field of view	17.5 mrad (1°)
Pixels per scan line	382
Scan rate	1.67 scan lines per second (100 rpm)
Spectral channels (μm; bandwidth (FWHM))	14 [a] (8 continuously sampled and last six in filter wheel): 0.340(0.009), 0.381(0.006), 0.472(0.021), 0.682(0.022), 0.870(0.022), 1.036(0.022), 1.219(0.022), 1.273(0.023), 1.556(0.032), 1.656(0.045), 1.737(0.040), 2.103(0.044), 2.205(0.042), 2.302(0.043)

Figure 1: Cloud Absorption Radiometer (CAR) on Jetstream-31 platform

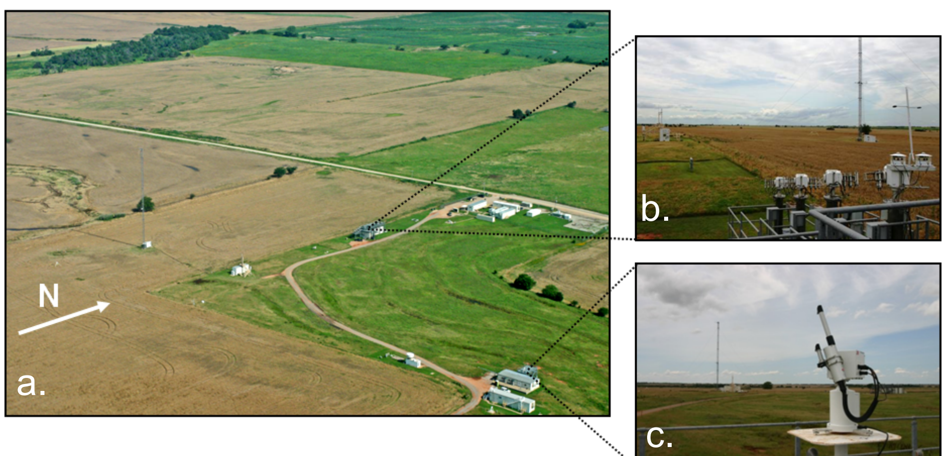


Figure 2: ARM Southern Great Plains Central Facility (Lamont, Oklahoma)

- A new retrieval strategy for fine to moderate resolution airborne multiangle observations was developed, based on the operational sequence used to retrieve the MODIS surface reflectance and BRDF/albedo products.
- Results offer empirical evidence concerning the role of scale and spatial heterogeneity in kernel-driven BRDF models; providing potential new insights into the behavior and characteristics of different surface radiative properties related to land/use cover change and vegetation structure.

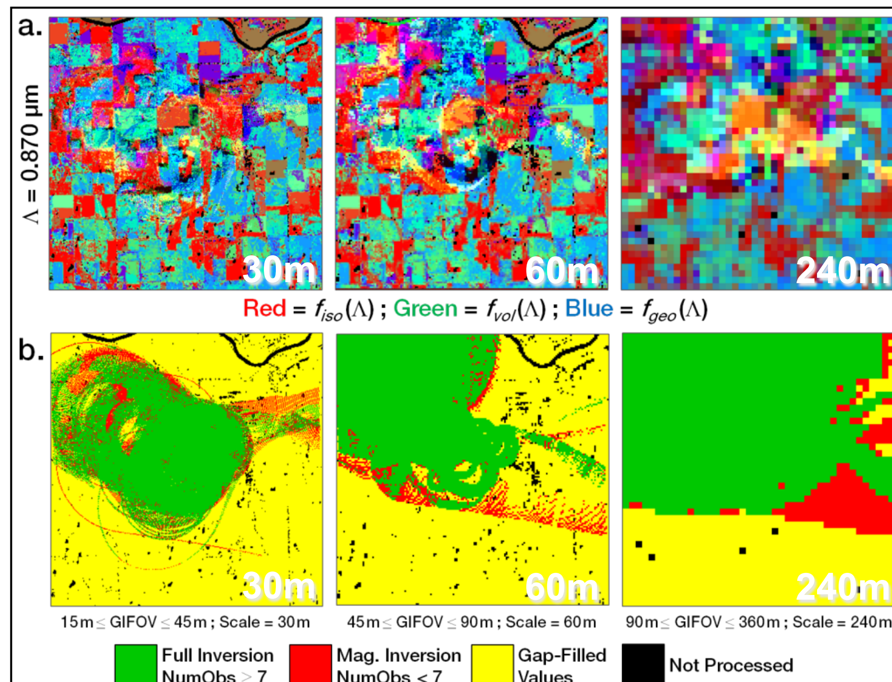


Figure 3: RossThick-LiSparseReciprocal (RTLSR) model parameters

Name: Miguel O. Román, NASA/GSFC
E-mail: Miguel.O.Roman@nasa.gov
Phone: 301-614-5498

References:

Román, M.O., C. K. Gatebe, C. Schaaf, R. Poudyal, Z. Wang, M. D. King, 2011: Variability in surface BRDF at different spatial scales (30 m–500 m) over a mixed agricultural landscape as retrieved from airborne and satellite spectral measurements *Remote Sensing of Environment*, *115*, 2184–2203, doi: 10.1016/ j.rse.2011.04.012

Data Sources: This is a joint effort between NASA-GSFC's Terrestrial Information Systems Branch (algorithm development and validation efforts), NASA-GSFC's Climate and Radiation Branch (CAR data acquisition and processing), and Boston University's Center for Remote Sensing (MODIS BRDF/ albedo data). CAR airborne datasets over the Atmospheric Radiation Measurement Program's (ARM) Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site in Oklahoma, USA (available at http://car.gsfc.nasa.gov/data/) were acquired during the 2007 Cloud and Land Surface Interaction Campaign (CLASIC) with support from NASA's Science Mission Directorate as part of the Earth Observing System (EOS) Radiation Sciences Program and Airborne Science Program (NASA Grants NNX08AF89G, NNX07AT35H, and NNX08AE94A); and the U.S. Department of Energy (DOE-DE-FG02-06ER64178).

Technical Description of Images:

(**Figure 1)** (a.) The N22746 aircraft registered to Sky Research Inc. (USA), also known as Jetstream-31 (J-31) in Ponca City Airport, Oklahoma, USA during the 2007 Cloud and Land Surface Interaction Campaign (CLASIC). (b.) Schematic of NASA's Cloud Absorption Radiometer (CAR), which is mounted in the nose cone of the J-31. The CAR measured the spectral and angular distribution of scattered light by clouds and aerosols, and obtained good imagery of clouds and Earth surface features over many areas in the U.S. Southern Great Plains Cloud and Radiation Testbed (CART) site. (c.) Illustration of a clockwise circular flight track that was used for measuring surface-level bidirectional reflectances. (d.) The CAR has 14 narrow spectral bands between 0.34 and 2.30 μm, and flew 11 missions during CLASIC.

(**Figure 2**) (a.) Bird's eye view of the CART site taken during CLASIC Flight #1922 (19 June 2007). (b.) Facing southwest atop the Radiometric Calibration Facility, overlooking the upward-facing pyranometers and the 60 meter radiation tower (20 June 2007). (c.) Facing west atop the Guest Instrument Facility, overlooking the AERONET sun photometer (20 June 2007).

(**Figure 3**) (a.) RossThick-LiSparseReciprocal (RTLSR) model parameters describing the BRDF at Λ = 0.870 μm for a 10 km^2 area surrounding the CART site. (b.) Per-pixel band-specific BRDF model inversion quality equivalent to the MODIS BRDF/Albedo quality Level 3 product (MCD43A2).

Scientific significance: This study provides new empirical evidence concerning the role of canopy shadowing and clumping on sensor geometry and spatial resolution. Since different structural elements may be responsible for the directional signature in moderate resolution satellite-based imagery (> 500m); clear validation strategies for obtaining spatially distributed BRDF products are thus essential to better identify factors affecting the state and ecological functioning of many ecosystems.

Relevance for future science and relationship to Decadal Survey: With its unique design (190° swath, 1° IFOV, oversampling every 0.5° along the vertical plane) and unparalleled instrument accuracy (≤5%), the CAR provides accurate representations of different ecosystem types across a broad range of retrieval scenarios. This capability is being used by different instrument science teams (e.g., MODIS, Landsat, and NPP-VIIRS) in support of meaningful product validation and intercomparison studies, as well as for research efforts that necessitate reference "proxy" datasets of uniform quality to monitor instrument performance and assess product quality.